Another study that investigated the relationship between roadway design attributes and collision activity was performed by Strathman et al (2001). This study investigated the statistical relationship between collision activity and roadway design attributes on Oregon highways. Using collision data from a two-year period (1997-1998), the highways were divided into variable length homogenous highway segments, yielding a set of over 11,000 segments. For non-freeway segments, maximum curve length and right shoulder width were found to be among the design attributes related to curves that were statistically related to collision activity. Maximum curve angle (a surrogate for degree of curvature) was not found to be related to collision activity in this study.

Souleyrette et al. (2001) evaluated roadway and collision characteristics for all highways in Iowa through integrating databases with digital imagery, roadway characteristics, and collision data. This project studied five collision types including collisions on horizontal curves and made use of the GIS technology to collect roadway characteristics that were not identified by collision records. Curves were found by using GIS to identify a 5º or more change in azimuth between tangents. The analysis of high collision locations on horizontal curves found that the degree of curvature had a direct impact on the collision rate. The model also indicated that the collision rate on shorter curve lengths was significantly higher than on longer curves. In addition, this study produced a curve database for Iowa with radii and length attributes and a procedure for identifying horizontal curves with high collision occurrences statewide.

Zegeer et al. (1991) analyzed over 13,000 horizontal curves, primarily in Washington, to evaluate the relationship between curve features and collisions. To meet the study objective, the horizontal curve features which affected traffic safety and operation were first identified. A collision prediction model (consisting of six variables relating to collisions and curve features) was developed through a variety of statistical methods. These six variables were: curve length, vehicles volume, degree of curve, presence of spiral transitions, and roadway width. From these identified variables, existing countermeasures for enhancing safety and operations at particular curve sections were determined and the model developed an effectiveness of collision reduction for each of these countermeasures. This study also provided general safety guidelines for curve design including signing, marking, and delineation as recommended cost-effective countermeasures.

Many other research efforts have examined specific curve collision countermeasures. However, to this point, as mentioned previously, no past study has characterized curve collisions on a large scale and matched the results of such a characterization with countermeasures directed at specific collision causes. Also, this paper provides recommendations on how an agency can conduct a comprehensive analysis of horizontal curve safety problems and deal with these problems in a systematic manner.

## 4.3  Methodology

The Highway Safety Information System (HSIS) collects and reports statewide collision data for participating states, which includes seven states with recent collision data (HSIS 2009). North Carolina was preselected as a data source by the Federal Highway Administration (FHWA) for inclusion in the HSIS program for its high quality collision,